Lessons learned developing remote sensing protocols for ecological monitoring at three western National Park networks

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Our group is involved with development of remote sensing-based monitoring protocols at four networks of parks. We began work on protocol development at the North Coast and Cascades network (NCCN) in early 2004, and the final protocol is now under anonymous external review. Work with the Northern and Southern Colorado Plateau networks (N&SCPN) began in mid-2005, with literature and data reviews now complete, and with a study plan under internal review by the networks. For the Southwest Alaska network (SWAN), we are currently processing an agreement that will allow us to begin work there in the first quarter of 2006. Although these park networks span a wide range of ecological and climatic conditions, several common themes have begun to emerge regarding the process for establishing the costs and benefits of different remote sensing technologies and regarding the likely methodologies for conducting monitoring.

Developing priorities for remote-sensing based monitoring is not a trivial or painless task. Typically, the list of monitoring objectives desired by a park network is much larger than can be readily accomplished within the budget constraints of any park or network. This is exacerbated when a network contains large-area parks, because remote sensing technologies that could be used to address some monitoring goals, such as small-footprint lidar or IKONOS, are too costly to extend to an entire park area when monitoring demands that they be purchased repeatedly into the future. Often, when monitoring goals are slightly re-stated, other options such as Landsat and MODIS can address the majority of the needs of many monitoring goals, but not all of them. Some goals may need to be dropped, or may be better suited for sample-based non-remote sensing approaches.

Several questions can start the process of re-stating and evaluating monitoring goals in the context of remote sensing. Does a given monitoring goal have attributes that make it distinguishable from background attributes? What spatial and temporal grain would be needed to track the changes in that attribute that signify a trend? Is it necessary to track this attribute over the whole park? Is the information from remote sensing relevant at the spatial grain of a single pixel, or are spatial patterns among pixels (grouped into patches, etc.) most relevant? How will models or maps from remote sensing be validated, and at what spatial and temporal grain will those validation efforts be needed? How much will it cost? Will the expertise for these technologies be developed in-house, or contracted out? In our experience with the three groups of networks described above, answers to the questions have begun to converge on a broad set of strategies.

First, Landsat data are the core of our efforts at all three networks. These data are of appropriate grain for both large-area and somewhat fine-grained monitoring and have appropriate spectral richness (especially sensitivity in the so-called short-wave infrared region) to capture many important trends. Moreover, they are cheap, consistent, and build on an archive of historical data whose value in establishing baseline conditions and measuring rates of change is invaluable. Although the immediate future of Landsat data is unpredictable, it appears as of this week that

Landsat 5 will continue acquiring data (despite problems with its solar array), that new Landsat 7 compositing methods will allow at least yearly acquisition of high-quality, low-cost data, and that the Landsat Data Continuity Mission (LDCM) has the Executive branch support and the institutional momentum to be on-track for data delivery in late 2010. For the purposes of monitoring over time at the parks we work with, even if there is a brief data gap in 2008-2009, it will likely cause minimal complication.

The second broad strategy emerging from these parks has been to track changes in cover condition in broad physiognomic terms. Detailed land cover maps remain critical for ecological monitoring, but the costs of modeling and validating changes in many highly site-specific cover classes have diminished their attractiveness to the parks for change monitoring. Additionally, re-evaluation of monitoring goals has suggested that many changes – even subtle or cover type specific changes – can be described as proportional changes in mixtures of these broader types. From this general strategy has emerged a specific methodology for tracking cover changes as changes in likelihood of membership in classes defined directly from knowledge of the biophysical properties of the spectral data space. Once defined and labeled, these changes can then be used to update more detailed maps over time, providing a compromise that leverages the contrasting strengths of static, single-date mapping and dynamic, cross-date change detection and labeling.

The third emerging strategy has been to place monitoring goals into two temporal groups, one requiring near-yearly and one requiring decadal change detection. Disturbance related goals require yearly or biennial change detection because recovery after disturbance can quickly obscure or confuse the initial disturbance signal. But these short intervals are too short to detect the slow changes associated with successional or community-replacement processes, making decadal change detection necessary. These represent ideal time-stamps which must sometimes be altered based on cloud-free image availability and on resources available for validation.

Validation is the core of the fourth broad strategy: maps need to be developed that can be validated in a realistic fashion by the parks given limited resources. Airphotos and ground-based field validation will only be feasible validation tools in limited areas or at sparse time intervals, making them appropriate only for certain monitoring goals. For other cases, direct expert interpretation of satellite imagery thus forms a key component of the strategy for monitoring at the parks. Satellite imagery will be interpreted using contextual rules and knowledge of the ecological system, and will be conducted in a probability-based design that allows assessment of accuracy of change maps. This constraint necessarily limits the cover type description to those that can be interpreted from Landsat imagery, which again has argued for tracking of changes in broad physiognomic terms.

Finally, all of the monitoring strategies are designed to lead to pixel-based based that can form the foundation of a variety of post-map analysis. For example, evaluation of extra-park land cover and land use dynamics will typically require inclusion of ancillary data, evaluation of patch or other super-pixel pattern, and will be summarized across larger areas. By providing a solid foundation with a clearly-defined error budget, a diverse range of later analyses can be built from the same foundational maps.